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NEST FEATURES AND NEST-TREE CHARACTERISTICS OF SHORT-TOED EAGLES (*CIRCAETUS GALLICUS*) IN THE DADIA-LEFKIMI-SOUFLI FOREST, NORTHEASTERN GREECE

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Abstract.—Data on nest features and nest-tree characteristics of 29 nest trees of Short-toed Eagles (*Circaetus gallicus*) were compared with the same number of paired, randomly-selected trees in the Dadia-Lefkimi-Soufli forest complex, northeastern Greece. Short-toed Eagles usually nested in Calabrian pine (*Pinus brutia*, 83%) trees that were either dominant (87%) or intermediate (13%) in the canopy. Most nests were in the largest trees in terms of height ($\bar{x}$ = 13.8 ± 0.4 m, ±SE) and diameter at breast height ($\bar{x}$ = 49.7 ± 1.6 cm) in stands. Nests were located in the lower or middle third of the canopy at a mean height of 8.6 ± 0.41 m and on horizontal branches at a mean distance of 133 cm ± 12.4 cm from trunks. A tendency for building nests on the south-facing side of canopies of nest trees was detected (mean angle = 178°, angular deviation s = 58°). Short-toed Eagles selected nest trees that provided them with easy access while also providing protection from predators and inclement weather.

Key Words: *Short-toed Eagle;* Circaetus gallicus; *nest features; nest-tree characteristics; Greece.*

Caracteristicas del nido y de los árboles con nido de *Circaetus gallicus* en el bosque Dadia-Lefkimi-Soufli en el noreste de Grecia

Resúmen.—Comparamos los datos sobre las características de 29 nidos de *Circaetus gallicus* con el mismo número de árboles seleccionados al azar en el complejo de bosques de Dadia-Lefkimi-Soufli en el noreste de Grecia. *Circaetus gallicus* anida usualmente en árboles de *Pinus brutia* 83% los cuales fueron dominantes (87%) o intermedio (13%) en el dosel. La mayoría de los nidos se encontraron en los árboles mas grandes en términos de altura ($\bar{x}$ = 13.8 ± 0.4 m, ±SE) en los rodales. Los nidos fueron localizados en la parte baja y el tercio medio del dosel a una altura media de 8.6 ± 0.41 m en ramas horizontales a una distancia media de 133 ± 12.4 cm del tronco. Se detectó la tendencia de construir los nidos en el costado sur del dosel (mean angle = 178°, angular deviation s = 58°). *Circaetus gallicus* seleccionó árboles que le proporcionaron un acceso fácil, como también protección de los depredadores y del inclemente clima.

[Traducción de César Márquez]

The Short-toed Eagle (*Circaetus gallicus*) is a tree-nesting accipitrid (Cramp and Simmons 1980), nesting in a variety of forest types, such as open coniferous forests in France (Thiollay 1968), dense evergreen oak and mixed deciduous woodland in central Italy (Petretti 1988), mixed conifer-deciduous forests in north-western Italy (Bocca 1989), and dry pine forests with mosses (*Sphagnum* spp.) in the ground layer in Belarus (Ivanovsky 1992). Despite considerable interest in the ecology of Short-toed Eagles in Mediterranean countries, few studies have been conducted to describe the structure of nest trees favored by the species (Petretti

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1988, Vlachos and Papageorgiou 1994). No previous studies have been attempted to describe and compare actual nest trees with available trees.

A detailed analysis of Short-toed Eagle nest trees in the Dadia-Lefkimi-Soufli forest complex was carried out to determine the most important characteristics determining the choice of nest trees. The aims of this study were to describe nest structure and to evaluate nest-tree characteristics of Short-toed Eagles by comparing actual nest trees with randomly-selected trees.

STUDY AREA

The study was conducted in the Dadia-Lefkimi-Soufli (D-L-S) forest complex, in the central part of Evros Prefecture, northeastern Greece (40°59′–41°15′N, 26°19′–26°36′E). The region is on the eastern edge of the Rodopi mountain chain in western Thrace. Elevations range from 20–700 m and steep-sided valleys crisscross the area. The climate is submediterranean and mean monthly temperatures in the area range from 25°C in July to 4°C in January. Mean annual precipitation is 664 mm. Northerly winds predominate during the year following the north-south orientation of the Evros valley.

The structure and composition of the vegetation in the D-L-S forest complex are the result of a combination of climate, soils, and intensive past human influence (Dafis 1973). The study area is covered by a mosaic of different habitat types, such as agricultural lands, grasslands, shrublands, rocky areas, pine forests, oak forests, degradated oak forests, and mixed pine-oak forests. The main overstory tree species are pines, including Calabrian pine (*Pinus brutia*) and black pine (*P. nigra*). The understory is mixed with pines, oaks (*Quercus conferta, Q. pubescens, Q. sessiliflora,* and *Q. cerris*), and various shrub species (*Phyllirea media, Arbutus andrachne, Erica arborea, Juniperus oxycedrus, Carpinus orientalis, Ostrya carpinifolia,* and *Fraxinus ornus*). Approximately 19.5% (7250 ha) of the 37 156 ha study area consists of two core areas that were established as protected areas for birds of prey in 1980.

The study area supports a remarkable diversity of wildlife including Black Vultures (*Aegypius monachus*), Griffon Vultures (*Gyps fulvus*), Lesser Spotted Eagles (*Aquila pomarina*), Imperial Eagles (*Aquila heliaca*), Booted Eagles (*Hieraaetus pennatus*), wolves (*Canis lupus*), jackals (*Canis aureus*), wild cats (*Felis sylvestris*), brown hares (*Lepus europaeus*), wild boars (*Sus scrofa*), large whip snakes (*Coluber jugularis*), grass snakes (*Natrix natrix*), dice snakes (*Natrix tesselata*), nose-horned vipers (*Vipera ammodytes*), and green lizards (*Lacerta viridis*) (Bakaloudis et al. 1998).

METHODS

As many occupied Short-toed Eagle territories as possible were located in the study area during the 1996–97 field seasons using (a) historical descriptions of traditional nesting sites, (b) territorial behaviors of breeding pairs noted from high vantage points, and (c) extensive exploratory surveys on foot (Fuller and Mosher 1987). A total of 29 nests were located in 22 Short-toed Eagle territories including occupied and old nests. Data on nest-tree characteristics were collected during August and September of 1996–97 after fledging. We recorded the following information to describe each nest tree: tree species, crown class (dominant, intermediate, or suppressed), trunk shape (straight, slightly crooked, crooked, forked, pitchforked, or without top), and canopy shape (condensed, dense, slack, or light). The condition of nest trees was described as good, medium (evidence of fire on bark), or bad (both evidence of fire and epiphytic growth). Nest-tree branches were measured and classified according to their density (I—>20 branches on the trunk, II—10–20 branches on the trunk, or III—<10 branches on the trunk) and their size as (thick—>50% of branches with a diameter >12 cm, medium—>50% of branches with a diameter 8–12 cm, or thin—>50% of branches with a diameter <8 cm). Diameter at breast height (dbh) was measured using a dbh tape and the age was determined using an increment core by counting growth rings. Height of nest trees, height of nests above ground, and height to living canopy were measured with a Blumme-Leiss altimeter (accuracy ±0.25 m). Canopy height of nest trees was estimated by subtracting the height of the bottom of the canopy to the ground from the height of the tree. Each nest was assigned to the lower, middle, or upper third of the canopy.

In order to compare nest-tree characteristics within the same forest stand, the same number (29) of nonnest trees were randomly selected from neighboring areas. Each random tree was situated from 70–400 m from nest trees. Three steps were followed to establish each random tree. First, the area centered on the nest tree was divided into four quadrants (1 = northeast, 2 = southeast, 3 = southwest, and 4 = northwest) and one of these was randomly selected. Secondly, two randomly-selected numbers between 0–400 were selected to calculate the distance of the random point along the north-south axis and the east-west axis. The intersection of lines extending from these points identified the location of the center of the random tree. Finally, the closest dominant tree to this centered point that was similar in dbh with the nest tree was selected and defined as the random nest tree (Titus and Mosher 1981). When random points identified points in nonforested areas such as grasslands, shrublands, and/or cultivated areas, or in an area with only young trees, they were rejected and the above procedure was reinitiated. The same measurements were made on the randomly-selected trees as nest trees, apart from variables concerning nest characteristics.

Nest features were described quantitatively in terms of the distance to the trunk of the tree in cm, the diameter of branches supporting nests against trunks in cm, maximum and minimum diameter axis of nests in cm, depth of nest cups in cm, and the height of the nest in cm. Nest orientation was determined as the mean flying direction to and from the nest, and nest orientation in relation to trunk was determined as the angle between a line joining the nest with the trunk and magnetic north. Nest orientation and nest orientation in relation to the tree trunk were measured with a compass, recording the angle in degrees from magnetic north.

All variables were tested for heterogeneity of variances using Bartlett's test (Zar 1996) and for normality using

Table 1. Characteristics of 29 Short-toed Eagle nests in the Dadia-Lefkimi-Soufli forest complex, northeastern Greece.

VARIABLE	MEAN ± SE	RANGE	CV
Height of nest above ground (m)	8.67 ± 0.41	5.5–12.25	20.47
Diameter of branch supporting the nest (cm)	12.46 ± 0.91	7.5–26	31.71
Distance from trunk (cm)	133.6 ± 12.4	45–231	38.72
Diameter of nest (cm) max.	61.75 ± 1.42	8–74	10.26
Diameter of nest (cm) min.	48.44 ± 1.06	40–59	9.52
Depth of nest-cup (cm)	7.17 ± 0.43	5–13	26.63
Height of nest (cm)	17.13 ± 0.93	12–26	23.74
Orientation of nest in relation to trunk (°)	178		
Orientation of nest (°)	171		

Anderson-Darling test. Variables that did not meet the assumptions of homoscedasticity and normality were log-transformed prior to parametric analysis. Normally-distributed variables were analyzed using paired-sample t-tests, but those not meeting normality assumptions after transformation were analyzed using the nonparametric equivalent Wilcoxon matched-pair test. Nominal variables were compared using chi-square analysis. We used Kolmogorov-Smirnov tests to test for uniformity in nest location in nest trees. Variables expressed as percentages were arcsine transformed to standardize variance. Circular variables were analyzed using Rayleigh's z test for circular uniformity (Batschelet 1981, Zar 1996). All statistical analyses were performed using the Minitab statistical software (version 12) and differences were considered significant with $\alpha = 0.05$.

RESULTS

Three types of Short-toed Eagle nests were recorded in the study area according to their position within the canopy of nest trees. Type I nests were located in the lower third of the canopy on large, horizontal forked branches and away from trunks. Type II nests were similar, but were located in the middle third of the canopy, and Type III nests were located on the top of relatively-flat canopies near to trunks and open from above. Nests were not distributed uniformly across the three nest types (Kolmogorov-Smirnov test; $D_{max} = 7$, $P < 0.05$) and were more often located in the lower or middle third than the upper third of the canopy.

Short-toed Eagles had a tendency to build nests on the south-facing sides of the canopy (mean angle = 178°, angular deviation $s = 58°$, measure of concentration $r = 0.49$; Table 1), which was significantly different from a uniform distribution (Rayleigh's test: $z = 6.84$, $P < 0.001$; Fig. 1a). The position of each nest offered incoming eagles a particular direction of approach to the nest. The mean orientation of nests was also south (mean angle = 171°, $s = 53°$, $r = 0.57$) and the distribution of orientation deviated significantly from random (Rayleigh's test: $z = 9.34$, $P < 0.001$; Fig. 1b). Nests generally were constructed using dead pine twigs, with or without needles, and oak twigs measuring 5–15 cm long and 1–3 cm in diameter. Nest cups were lined with green pine needles and green oak leaves. Materials were added to nests by adult eagles during the breeding season until young eagles fledged from nests. Nests measured on average 61.7 ± 1.4 × 48.4 ± 1.1 cm ($N = 29$). Short-toed Eagles tend to build new nests each breeding season. In a sample of 35 nesting attempts in the study area during 1996–97, seven pairs repaired and reused the same nest for two consecutive years and three pairs used the same nest for more than two years (unpubl. data).

Short-toed Eagles nested exclusively in Calabrian (83%) and black (17%) pines. All nest trees were alive and fell into the largest diameter size classes. The structure of nest trees was similar to random nest trees (Table 2). We could not detect a difference between nest tree and randomly-selected trees in terms of their dbh, height, canopy height, or age. Nest trees were either dominant (87%) or intermediate (13%) in the canopy; random trees were all dominant (2 × 2 contingency test, $\chi^2 = 2.071$, df = 1, $P = 0.150$). Nest trees had either slightly crooked (90%) or straight (10%) trunks, which was not significantly different from random trees (93% slightly crooked, 7% straight) (2 × 2 contingency test, $\chi^2 = 0.25$, df = 1, $P = 0.61$). Additionally, there were no differences between nest trees and randomly-selected trees in canopy shape (2 × 3 contingency test, $\chi^2 = 3.39$, df = 2, $P = 0.18$) or the condition of the trunk (2 × 3 contingency test, $\chi^2 = 0.9$, df = 2, $P = 0.63$). However,

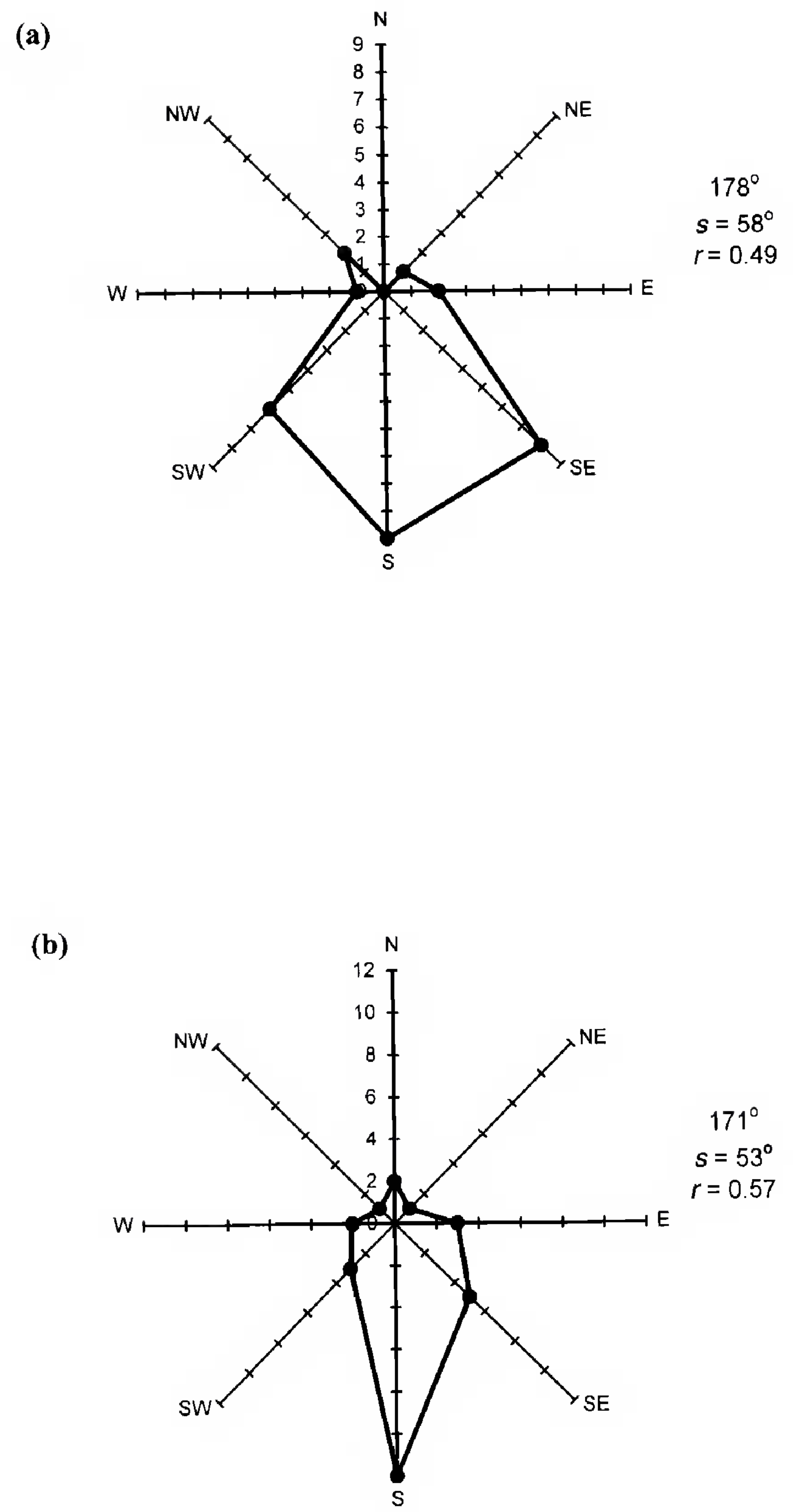

Figure 1. (a) Orientation of Short-toed Eagle nests in relation to nest-tree trunk and (b) orientations of flight path of Short-toed Eagles to and from nests in the Dadia-Lefkimi-Soufli forest complex (N = 29).

the majority of nest trees had many (42%) and some (55%) branches, as opposed to random trees which had only some (65%) and few (28%) branches (2 × 3 contingency test, χ^2 = 12.84, df = 2, P = 0.002). Branches were also thicker in nest trees than in random trees (2 × 3 contingency test, χ^2 = 9.68, df = 2, P = 0.008).

DISCUSSION

Short-toed Eagles were found to use mostly Calabrian (83%) and black (17%) pines for nesting in our study area. Calabrian pine trees generally have only a few, thick branches and an oval-shaped canopy. Black pines have many more and thinner branches with a relatively flat canopy. These differences may explain the Short-toed Eagle's preference for Calabrian pines for nesting. In the same study area, similar findings were also demonstrated by Vlachos and Papageorgiou (1994) who found that 80% and 20% of nests were built on Calabrian and black pines, respectively. In Belarus, Short-toed Eagles nest exclusively in pines (Ivanovsky 1992). In northwestern Italy, they nest in *Larix decidua* and *Pinus silvestris* (Bocca 1989) and in central Italy they nest in evergreen oak and deciduous trees (Petretti 1988).

Table 2. Characteristics of 29 Short-toed Eagle nest trees and 29 randomly-selected mature trees in the Dadia-Lefkimi-Soufli forest complex, northeastern Greece ($\bar{x}$ ± SE). P-value indicates statistical significance of difference between the pairs of means.

VARIABLES	NEST TREE	RANDOM TREE	P-VALUE
dbh (cm)	49.7 ± 1.6	47.9 ± 0.6	0.66[a]
Height (m)	13.8 ± 0.4	14.2 ± 0.4	0.38
Canopy height (m)	5.8 ± 0.3	6.0 ± 0.2	0.38
Age (years)	87.5 ± 3.1	85.3 ± 3.0	0.51

[a] Value based on paired sample Wilcoxon test.

All nest trees were dominant with mean height and mean height of canopy of 13.8 and 5.8 m, respectively. Nest trees were also mature ranging from 72–135-yr old and they belonged to the highest diameter size classes with a mean dbh of 49.7 cm. Short-toed Eagles showed a preference for building their nests in trees containing thicker branches and >10 branches per trunk. Trees with this structure probably provide greater shelter from predators and inclement weather while, at the same time, provide support for nests (Solonen 1982). Such trees are the result of a lack of competition during early successional stages (Dafis 1990) or from varying intensities of competition experienced over time (Begon et al. 1996).

Short-toed Eagles preferred to build their nests on the south-facing side of the canopy of nest trees. We suggest several reasons they do this. First, the strong relationship between nest position in relation to trunk and slope orientation offers a particular direction for adults to access nests (Newton 1979, Sieg and Becker 1990) and provides a favorable setting for fledglings when they first fly from nests. Petretti (1988) also noted that 42.8% of Short-toed Eagle nests in Italy were situated on lateral branches overlooking steep slopes. Secondly, a preferred orientation for nests has also been observed in several raptors and may be related to breeding performance (Vinuela and Sunyer 1992) by providing a favorable environment both for the incubating female and nestlings. The main meteorological factors that might influence nest orientation and reproductive success are temperature early in the breeding season, direct solar radiation during hotter days, and avoidance of other inclement conditions. In D-L-S forest complex, Short-toed Eagles probably gain warmth in the beginning of breeding season when temperatures are still low by situating nests to the south sides of nest trees. Similarly, Ivanovsky (1992) in Belarus, found that nests were directed towards the south or southeast when they were situated below the top of trees. Mosher and White (1976) in Alaska and Poole and Bromley (1988) in the central Canadian Arctic noted the tendency for Golden Eagles (*Aquila chrysaetos*) to place their nests in a southeasterly direction and Buchanan et al. (1993) have recorded a mean southeasterly direction for Spotted Owl (*Strix occidentalis*) nests in the Cascade Mountains in Washington for Spotted Owl nests. Additionally, Tjernberg (1983) in Sweden, has mentioned the preference of Golden Eagles to breed on cliffs facing south or southwest.

Eighty-six percent of the nests were located within the foliage of nest trees on large horizontal branches at a mean distance of 133 cm from trunks. Shadowed by a roof of branches from above, these nests probably provide both concealment from other avian predators (Newton 1979) and direct insulation from the sun. Short-toed Eagles build their nests in foliage to protect incubating females, eggs, and nestlings from aerial avian predators (e.g., Eagle Owls [*Bubo bubo*], Common Ravens [*Corvus corax*], and Hooded Carrion Crows [*Corvus corone cornix*]), which were common in the study area. In addition, branches above nests provide cover from direct solar radiation minimizing thermal stress in newly-hatched nestlings, especially during the hottest days when, in some cases, the temperature rises to 40–43°C.

In our study area, the predominant winds are northerly and the majority of the storms arrive from the north (Flokas 1990). Overall, the placement of nests by birds opposite to prevailing winds and storms may be critical to avoid the most inclement weather (Colias and Colias 1984). In the Doñana National Park, Spain, where westerly winds prevail, Black Kites (*Milvus migrans*) build their nests on the leeward sides of tree crowns maximizing the sheltering effect of trees (Vinuela and Sunyer 1992). At Sagehen Creek in California, where inclement weather is mainly from the south, American Kestrels (*Falco sparverius*) situate their nests to avoid this cold direction (Balgooyen 1976, 1990, Raphael 1985). Similarly, Olsen and Olsen (1989) in Canberra, Australia, noted that only 10.3% of Peregrine Falcon (*Falco peregrinus*) nests faced southwest where most inclement weather originated.

In our study, nest features of Short-toed Eagles agreed with those reported in previous studies. Newton (1979), Petretti (1988), and Vlachos and Papageorgiou (1994) noted the tendency for Short-toed Eagles to build small nests for their body size, and to build a new nest in a different place each year. Petretti (1988) reported a total of 39 nesting attempts, but the same nest was used in two consecutive years twice and for three consecutive years only once. Ivanovsky (1992) reported that each pair had 1–9 alternate nests, and the distance between them varied from 300–1500 m. Eagles in our study differed in that they tended to maintain the same nests for longer periods of time, or to use another nest in close proximity to the first. This may have been due to nest site competition with other raptors. The D-L-S forest complex supports a diverse concentration of raptors which possibly creates strong interspecific competition for nesting sites (Vlachos 1989). Another explanation is that Short-toed Eagles are possibly at carrying capacity in the D-L-S forest complex (Hallman 1979) and so remain, year after year, at the same nest sites because no other sites are available.

We observed Short-toed Eagles frequently carrying green twigs to their nests, a behavior that has also been noted by Petretti (1988). Newton (1979) reported this habit for other raptors, and many explanations including nest sanitation and the maintenance of optimum humidity have been suggested for this behavior. The most widely accepted explanation is that raptors bring green vegetation to their nests to advertise territory occupancy (Newton 1979). A further explanation is that the continual addition of nesting material increases the size of the nest to accommodate the increasing size and activity of the nestlings, particularly when they begin to exercise their wings (Newton 1979). Perhaps this is more important for Short-toed Eagles because they build very small nests in comparison to their size.

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